Generation IV Roadmap Overview

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Outline

1. Roadmap project overview
2. Generation IV International Forum
3. Fuel cycle context
4. Evaluation methodology approach
5. R&D Plan

Objective – Gen IV Technology Roadmap

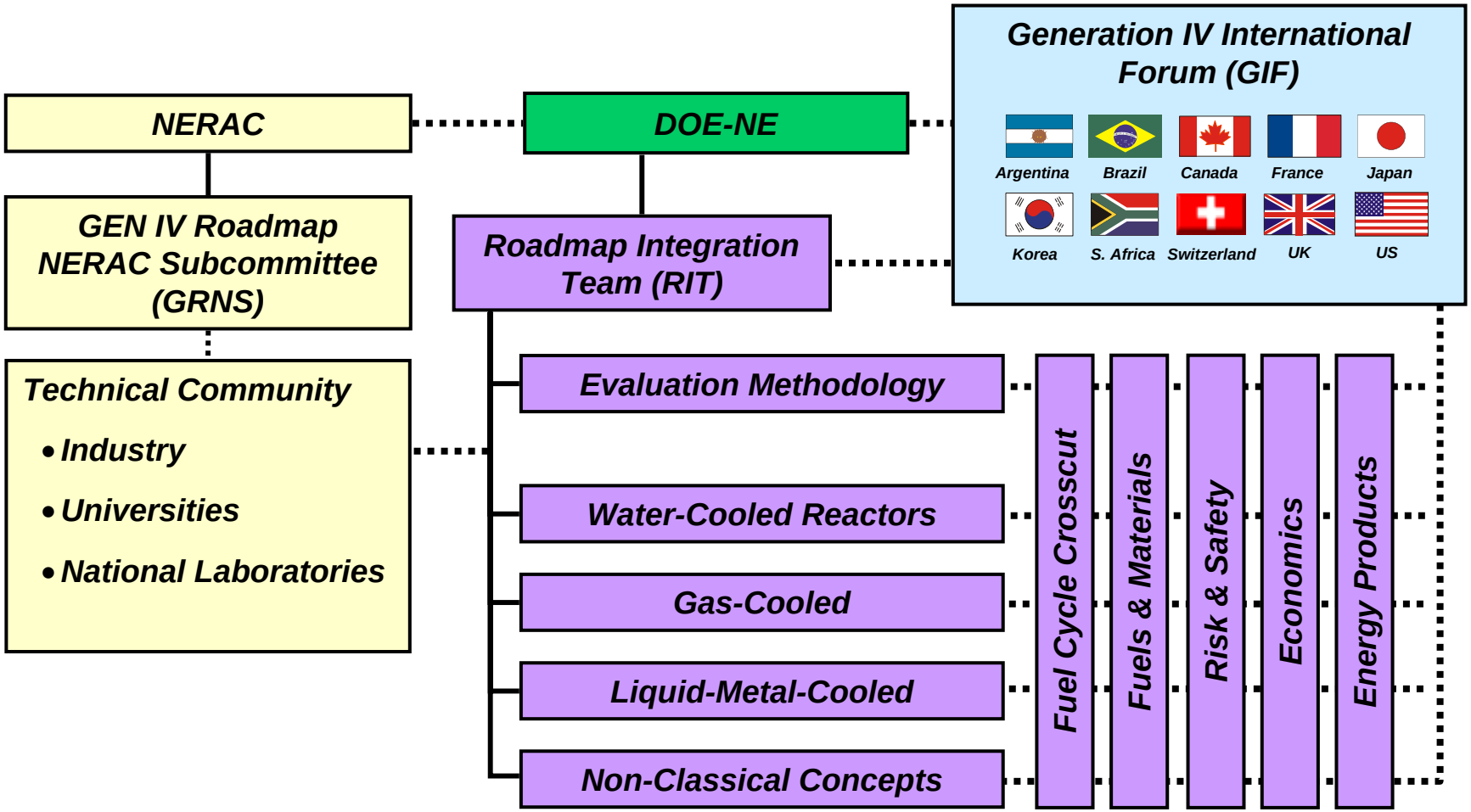
The Technology Roadmap:

- ***Describes systems deployable by 2030 or earlier***
- ***Determines which systems offer significant advances towards:***
  - ***Sustainability***
  - ***Safety and reliability***
  - ***Economics***
- ***Examines R&D pathways for nuclear technology***
- ***Plans for a Generation IV R&D program***

Key Steps for the Roadmap

- *Define Technology Goals for Generation IV*
  - *Technology Goals Document* — *March 2001*
- *Identify Concepts with Potential*
  - *Broad Request for Information* — *April 2001*
- *Evaluate Concepts with a Common Methodology*
  - *Qualitative Screening for Potential* — *Sep 2001*
  - *Quantitative Final Screening* — *Mar 2002*
  - *Selection of concepts* — *(underway)*
- *Identify R&D Gaps and Needs* — *(underway)*
- *Assemble a Program Plan*
  - *Integration and writing:* — *Summer 2002*

Roadmap Organization



GIF Charter and Operation

Charter signed in July 2001 to:

- ***Identify potential areas of multilateral collaborations on Generation IV nuclear energy systems,***
- ***Foster collaborative R&D projects,***
- ***Establish guidelines for the collaborations and reporting of their results,***
- ***Regularly review the progress and make recommendations on the direction of collaborative R&D projects,***

Operation of the GIF:

- ***No permanent staff or centralized funding of projects***

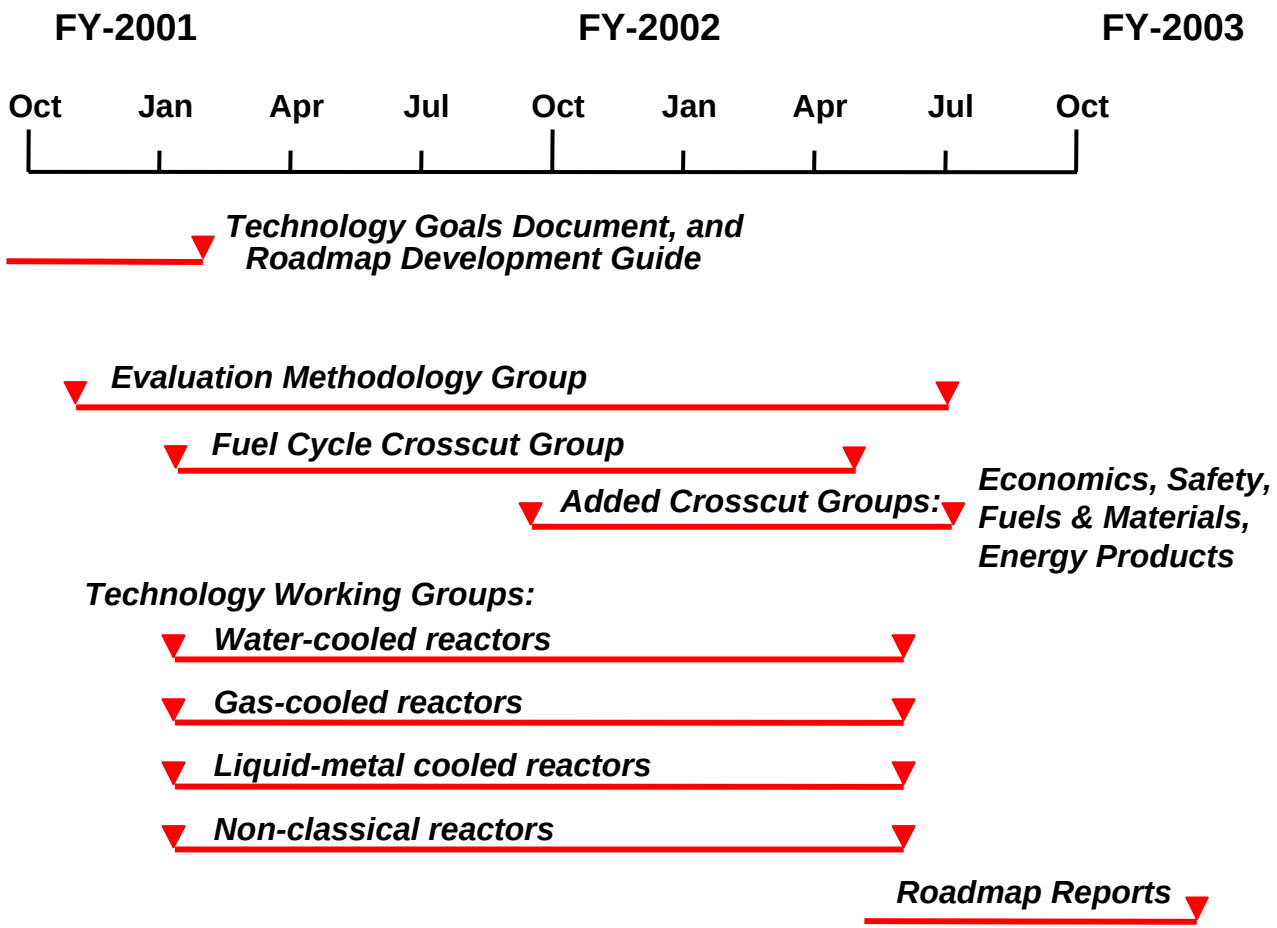
GIF Roles in Generation IV

- *Sponsors nearly 50 staff on the roadmap*
- *Reviews and brings international perspective*
  - *Gen IV Technology Goals*
  - *Gen IV Roadmap*
- *Endorses key elements: Concepts, Roadmap*
- *Collaborates on Generation IV R&D*

GIF Meetings

January 2000	Washington	Countries support Gen IV idea
April 2000	Washington	Experts convened on path forward
August 2000	Seoul	Comment on goals, write charter
March 2001	Paris	Finalize charter, support roadmap
October 2001	Miami	Comment on methodology
February 2002	London	Discuss concepts and selection
April 2002	Washington	Review concept evaluations
May 2002	Paris	Select 6-8 long-term concepts
July 2002	Rio de Janeiro	Review R&D plans
November 2002	Tokyo	Plan R&D collaborations

Two-year Gen IV Time Envelope



Eight Goals within Three Goal Areas

Sustainability

Resource inputs	**SU-1: Generation IV nuclear energy systems including fuel cycles will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.**
Waste outputs	**SU-2: Generation IV systems will minimize and manage their nuclear waste and notably reduce the long term stewardship burden in the future, thereby improving protection for public health and the environment.**
Nonproliferation	**SU-3: Generation IV nuclear energy systems including fuel cycles will increase the assurance that they are a very unattractive and least desirable route for diversion or theft of weapons-usable materials.**

Safety & Reliability

Excellence	**SR-1: Generation IV nuclear energy systems operations will excel in safety and reliability.**
Core damage	**SR-2: Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.**
Emergency response	**SR-3: Generation IV nuclear energy systems will eliminate the need for offsite emergency response.**

Economics

Life cycle cost	**EC-1: Generation IV nuclear energy systems will have a clear life-cycle cost advantage over other energy sources.**
Risk to capital	**EC-2: Generation IV nuclear energy systems will have a level of financial risk comparable to other energy projects.**

Full Technology Goals document (8 pages) is available at: gen-iv.ne.doe.gov/pdf/finalgenivgoals_may01.pdf

Concept Evaluation

Broad Request for Information (Apr 2001)

- ***Over 100 ideas submitted, about 1/3 international***

Qualitative Screening (Sep 2001)

- ***Qualitative criteria for each Gen IV goal***
- ***Many ideas combined into 30 concepts, a few did not advance***

Quantitative Evaluation (Mar 2002)

- ***Further refinement into 19 concepts***
- ***Quantitative criteria and metrics***

Selection of Most Promising Long-term Systems

- ***Discussed at the April & May GIF meetings***

System Concepts

Reactor System	Fuel Cycle
Integral Primary System Reactors	LEU Once-through
Simplified Boiling Water Ractors	LEU Once-through
CANDU Next Generation	DUPIC – partial fissile recycle
Supercritical Water Reactors – Thermal Spectrum	LEU Once-through
Supercritical Water Reactors – Fast Spectrum	Full actinide recycle
High Conversion Boiling Water Reactors	Full actinide recycle
Pebble Bed Modular Reactors	LEU Once-through
Prismatic Modular Reactors	LEU Once-through
Very High Temperature Reactors	LEU Once-through
Generic High Temperature Gas Reactors – Closed Cycle	Full actinide recycle (U,Th)
Gas Fast Reactor	Full actinide recycle
Sodium cooled, MOX fuel, advanced aqueous process	Full actinide recycle
Sodium cooled, metal fuel, pyroprocess	Full actinide recycle
Medium Pb/Pb-Bi cooled, Russian design	Full actinide recycle
Medium Pb/Pb-Bi cooled, US design	Full actinide recycle
Small Pb/Pb-Bi cooled	Full actinide recycle
Liquid Core (Molten Salt) Reactors	Full actinide recycle (U,Th)
Vapor Core Reactors	Full actinide recycle
Molten Salt Cooled Prismatic Fuel Reactor	LEU Once-through

Background: Gen IV Fuel Cycle Studies

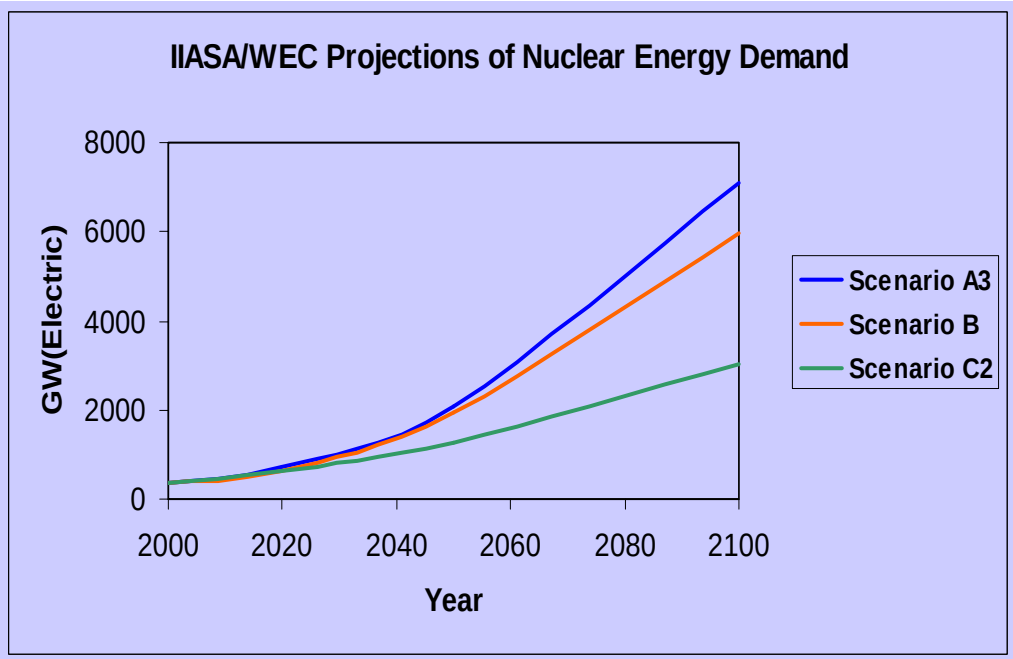
- *Fuel Cycle Crosscut Group (FCCG) assessed impact of fuel cycle options on key elements of sustainability*
  - *Waste generation*
  - *Resource utilization*
- *Four generic fuel cycle options were evaluated:*

  Once through (baseline case)

  Limited Fissile Recycle

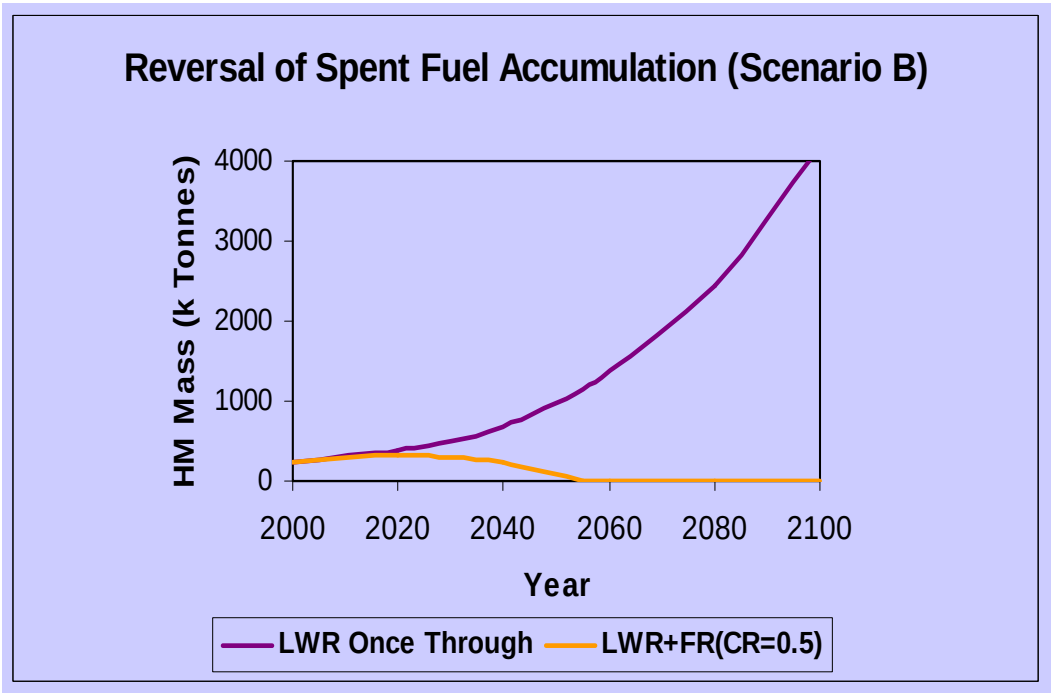
  Full Fissile Recycle

  Full Actinide Recycle
- *Options were modeled over the next century based on the recent IIASA/WEC nuclear energy demand projections*
  - *B: Reference (Middle course)*
  - *C2 Efficiency & Expanded Nuclear*



Fuel Cycle Study: Main Findings

- *Use of the once through cycle leads to*
  - *Accelerating repository siting needs*
  - *Exhaustion by mid-century of known + speculative high-grade ore*
- *Closing the fuel cycle is the principal means of achieving*
  - *Reduced waste quantity and radiotoxicity*
  - *Waste forms optimized for durability and leach resistance*
  - *Optimal use of repository capacity via decay heat management*
  - *Resource extension via recovery of fissile material*
- *Symbiotic use of fast and thermal reactors is needed to limit waste disposal challenges and overall system cost*



Evaluation Method Philosophy

- *Evaluate the potential for the systems to advance toward the Generation IV goals*
- *Treat all Generation IV goals equally*
- *Strive for comprehensive evaluations, but accept qualitative judgement*
- *Allow for systems with different levels of maturity*
- *Do not discriminate against less well developed systems*

Criteria and Metrics Overview

- *Create criteria that:*
  - *Reflect the breadth of the Generation IV Goals*
  - *Can indicate significant progress toward Goals*
  - *Will discriminate on system potential*

- *Create metrics that:*
  - *Are quantitative where possible*
  - *Contribute to future key information:*
    - *Safety analysis*
    - *Environmental*
    - *Business case*

The criteria are only a sampling of all that are possible

Rollup of Criteria, Goals and Goal Areas

3 Goal Areas

Sustainability	Safety and Reliability	Economics

8 Goals

Sustainability	Safety and Reliability	Economics
SU-1 Fuel Utilization SU-2 Waste Minimization SU-3 Nonproliferation and Physical Protection	SR-1 Operational Safety & Reliability SR-2 Core Damage SR-3 Offsite Emergency Response	EC-1 Life Cycle Cost EC-2 Risk to Capital

24 Criteria

Sustainability	Safety and Reliability	Economics
Fuel utilization Waste mass Volume Heat load Radiotoxicity Environmental impact Separated materials Spent fuel characteristics Passive sabotage resistance	Reliability Worker – routine exposures Worker – accidents Reliable reactivity control Reliable heat removal Dominant phenomena certainty Long fuel thermal response time Integral experiments scalability Source term Mechanisms for energy release Long system time constants Long and effective holdup	Overnight construction cost Operational costs Construction duration Overnight construction cost Construction duration

Beyond Technology Goals: Missions

- *The purpose of 'Missions' is to assure that the selected Generation IV concepts will adequately address a variety of important future needs, especially those for alternative energy products and fuel cycles*

- *Four major missions have been proposed:*
  - *Large Grid Electricity Producer (E1)*
  - *Small Grid Electricity Producer (E2)*
  - *Hydrogen/High Temperature Process Heat (H)*
  - *Actinide Management (AM), consisting of both waste burndown and fissile creation*

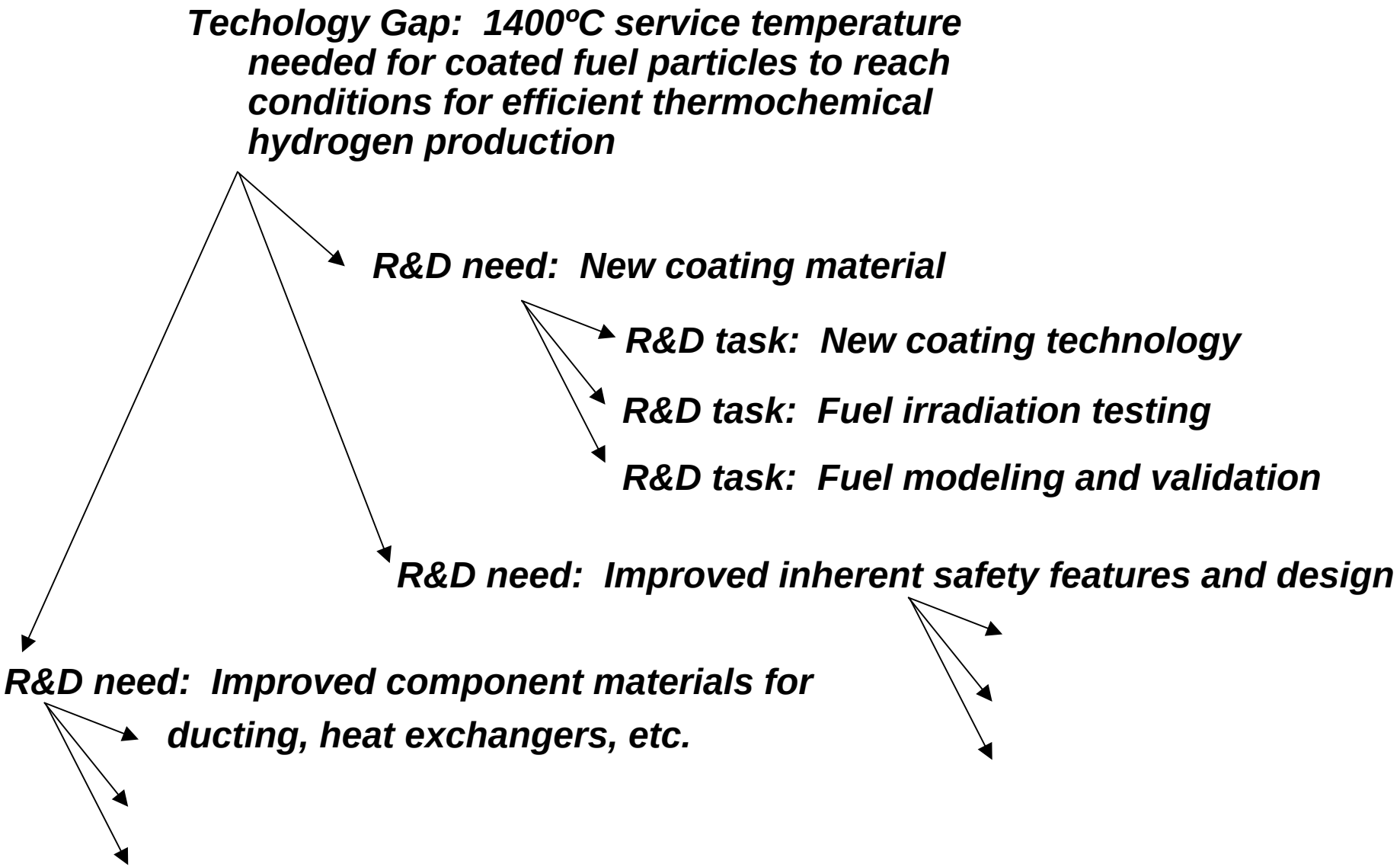
Other Important Considerations

- *R&D Costs*
- *R&D Risks*
- *Expected length of time for RD&D to deployment*
- *R&D interdependencies between systems (R&D pathways)*
- *National policies and priorities*
- *Public confidence*

Selected Highlights of the R&D Challenges

- *Higher temperatures for fuels and materials*
- *Increased corrosion/erosion in alternative coolants*
- *Design with inherent safety*
- *Fuel fabrication methods*
- *Recycling technology and methods*
- *Manufacturing and constructability*
- *Hydrogen by thermochemical processes*
- *Component technologies to match coolant conditions*
- *Controls and Human-Machine Interface for modular plants*

R&D Scoping: Gaps and Needs Example



Schedule for Completion

- *Finalization of concept selection* — *May ’02*
- *R&D Integration* — *July ’02*
- *Roadmap Report finalized* — *Sep ’02*
- *Transmittal to NERAC and GIF* — *Fall ‘02*

Summary

- *The roadmap is a two-year project, to be completed at the end of FY-02*
- *The primary objective of the Roadmap is to define an overall R&D plan to advance the next generation, with significant international participation of the 10 countries in the Generation IV International Forum*
- *Nearly 100 international experts staff the working groups, with significant industrial participation*
- *Over 100 ideas and concepts have been refined to about 20 most promising concepts; the objective is to get to the 6-8 with the best long-term potential and develop an R&D program that advances them*